A PRELIMINARY TEST OF TWO MODELS FOR HUMAN FACTORS ANALYSIS OF OPERATIONAL ERRORS

Julia Pounds, Ph.D.
Human Factors Research Lab
Civil Aeromedical Institute
FAA

Anne Isaac, Ph.D.
European Air Traffic Management Programme
EUROCONTROL

ABSTRACT

As the congestion and complexity of airspace continue to grow, the importance of identifying the human factors contributing to separation violations between aircraft will increase. An air traffic controller's ability to maintain high levels of performance is becoming increasingly interdependent with advanced interfaces and computerized support technology. Therefore, appropriate methods for investigation and identification of human factors related to maintaining separation standards are needed by aviation incident investigators and human factors researchers. This paper reports on one of a series of activities to harmonise two human factors techniques developed for retrospective investigation of human errors in aviation systems: The Human Factors Analysis and Classification System (HFACS; Shappell & Weigmann, 2000) and the Human Error in ATM Technique (HERA; EATMP, 2000). A comparison of the two techniques was conducted by having an air traffic control (ATC) subject matter expert (SME) analyse a common set of incident reports using both. Results demonstrated that HFACS captured human factors at a categorical level, while HERA identified specific cognitive processes. Future work will build on the strengths of both techniques to create a retrospective method for investigation of human error in operational errors.

BACKGROUND

Human errors in air traffic management/air traffic control (ATM/ATC) are defined by Isaac and Ruitenberg (1999) as "intended actions which are not correctly executed" and "any act which results in an incident or accident that may involve personal injury/death, and/or property damage" (pg. 11). To comprehensively examine human error in air traffic control, one should consider the timeline of the event and the full range of tasks and actions that characterise an air traffic controller's performance over time. When one views the loss of separation as the final event preceded by a cascade of interconnected antecedent events, there are likely multiple opportunities to intercede and change the final outcome.

Research has demonstrated that breakdowns in cognitive processes such as attention, judgment, and communication have been causal factors in reported operational errors in the US airspace. For example, early analyses by Kinney, Spahn, and Amato (1977) found that 95% of separation violations from en route centers that were classified as operational errors involved controller errors in attention, judgment, or communications. These same error types repeatedly have been found in other studies of ATC operational errors (e.g., Redding, 1992; Rodgers & Nye, 1993; Schroeder, 1982; Stager & Hameluck, 1990).

To better understand the genesis, distribution, and effects of human errors on air traffic control performance, the FAA and EUROCONTROL are collaborating on the development of a model-based technique to investigate human errors in air traffic control. Models are useful for the analysis of human behavior because they provide a framework to guide the investigation, as opposed to research driven by special interests or fads of the moment (Shappell & Wiegmann, 2000).

In 1999, FAA and EUROCONTROL representatives signed Action Plan 12: Management and Reduction of Human Error in Air Traffic Management. The scope of the ongoing work includes harmonization and joint application of the European and US approaches for analyzing human errors in aviation incidents. As part of the project, analytic methods for retrospective analysis of incidents and prospective approaches for analysis of new and evolving systems will be developed and evaluated.

Two techniques are being utilized for this effort. The US technique being employed is

HFACS, developed by Shappell and Wiegmann (2001). HFACS is a human error approach originally developed for aviation accident investigation initially as a cause-oriented rather than outcome-oriented investigation taxonomy that could be used in multiple occupational settings in addition to aviation. HFACS examines human error as part of a larger, complex, productive system by combining multiple definitions of "human factors" into a coherent taxonomy and adopting a systems perspective for investigating and preventing aviation accidents. Namely, human error is evaluated as one part of a larger systemic problem. Latent failures at the organizational or supervisory levels, for example, can contribute to an active failure in operator performance. HFACS categories represent 4 levels of behaviors: 1) unsafe acts of operators, 2) preconditions for unsafe acts, 3) unsafe supervision, and 4) organizational influences. To date, the framework has been adopted by the U.S. Navy, Marine Corps, Army, Air Force, and Canadian Forces.

The EUROCONTROL technique is HERA—the Human Error in ATM classification system (EATMP, 2000). HERA analysis evaluates the air traffic incident in its ATM context by identifying the ATC behavior, the equipment used, and the ATC function being performed. HERA is based on human performance models and taxonomies of human error. A review of current and future ATM systems and task analyses were used to establish the ATM context for the technique. Based on these reviews, HERA was developed to consider the operator as part of a larger system and to expand investigation of the human performance factors beyond the individual by including different facets of the situation to understand the mechanisms and context leading to the error. HERA categorizes human error on several dimensions, including the task being conducted, the characteristic of the failed behavior, psychological error mechanisms, and performance shaping factors, such as traffic, airspace, and workplace design.

A descriptive analysis of a set of incident cases was conducted to compare and contrast output from the two techniques. Areas of overlap would suggest that a more parsimonious analytic approach could be developed through harmonization rather than using the two techniques separately. A second purpose was to determine whether the models were too disparate to be harmonized at all. That is, if the techniques were too dissimilar, harmonization might not be feasible.

METHOD

An ATC SME was employed to conduct the analysis. He possessed more than thirty years of air traffic control experience and had held military, civilian control, and management responsibilities in both terminal and en route facilities. The SME was trained in both HFACS and HERA techniques and did not have any other human factors training beyond what was afforded by ATC training and experience and what was gained during the project.

Each technique was used to analyze narrative descriptions of separation events. The narratives were part of the final incident report to the FAA Office of Investigations by air traffic service facilities as part of the investigation of operational error (OE) events. The final report of an OE includes an extensive listing of descriptive data followed by a narrative summary. Each narrative can include up to three sections: a timeline of the event, a short summary of the event, and statements that elaborate on specific items from the body of the report. These narratives from the reports were extracted from the FAA OE report database. Not all of the three sections were available for all events.

The same set of narratives was analyzed using both techniques. First, the ten incident narratives were analyzed using the HFACS technique and then re-analyzed using the HERA technique.

RESULTS

Figure 1 shows the overall frequencies of identified failure points at each of the HFACS tiers for the 10 narratives as categorized by the HFACS analysis. As shown, at least one Unsafe Act was identified in each narrative. There were few latent failures to be classified as Preconditions for Unsafe Acts, Unsafe Supervision, and Organizational Influences tiers. This was attributed to the current reporting system (from which the narratives were extracted) which does not specifically elicit information on these dimensions. Table 1 lists several items identified as part of the HFACS analysis.

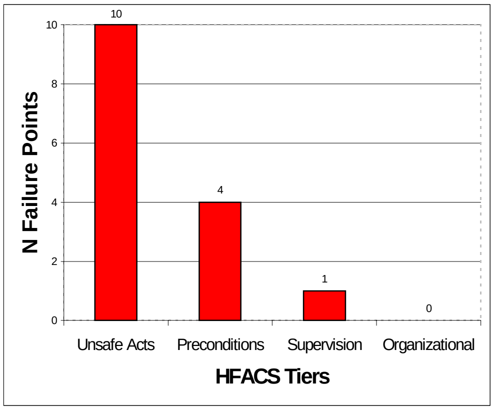

Figure 1. Distribution of failure points resulting from HFACS analysis.

Table 1. Examples of HFACS output:

Unsafe Acts:

- Did not resolve all real or potential conflicts before changing A/C to another sector's frequency.
- Descended aircraft on assumption of outcome without insuring separation.
- Forgot about military area requirements.
- Said the wrong altitude after making a manual altitude input in data block.
- Failed to observe displayed data and so did not recognize the need for separation.

Preconditions for Unsafe Acts:

- Did not have the complete picture of the traffic situation before issuing climb to conflicting traffic.

Figure 2 shows the frequencies of identified failure points in the HFACS Unsafe Acts tier broken down into the respective categories. Because of limitations associated with the small amount of data, especially in the upper tiers of HFACS, further analysis was not possible.

Table 2 lists a sample of the output from the HERA analysis of the same 10 narratives. On inspection, the data output from the HERA analysis are distinctly different from that of the HFACS analysis, although both techniques were developed from similar human error research literature.

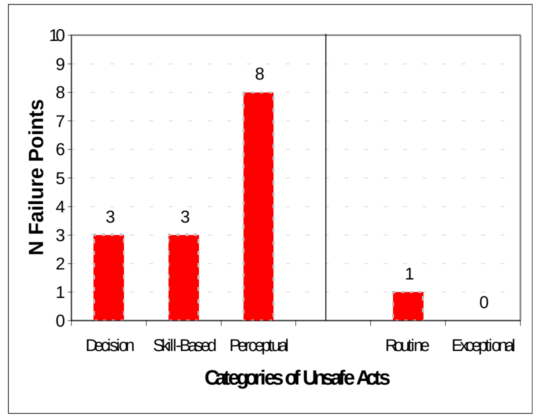

Figure 2. Distribution of failure points within the Unsafe Acts tier of HFACS.

Table 2. Results of HERA analysis.

Task	
Planning	10
R/T Communications	8
Radar Monitoring	6
Equipment	
Radio	2
External Behavior	
Wrong action	5
Mis-ordering	2
Cognitive Domain	
Perception & Vigilance	5
Working Memory	2
Internal Error Modes	
No visual detection	3
Late visual detection	2
Forgot previous actions	1
Psychological Error Mechanisms	
Expectation bias	4
Distraction	2
Visual search failure	1
Performance Shaping Factors	
Weather	5
Complex traffic mix	4
Traffic underload	4
Excessive traffic load	3

CONCLUSIONS

Examination of the output from the two analyses revealed that each technique has unique strengths and distinctly different output. Both are comprehensive but focus at different levels of detail. Both were user-friendly for an ATC SME who was a human factors novice. By harmonizing the two into a single technique and incorporating the advantages of both, a more complete picture of the event might be possible.

HFACS provides a quick, user-friendly, categorization scheme and has been successfully used by accident investigators to track relative changes in incident data over time. The output from the HFACS analysis has a textual format that can be used in further content analyses. Given the appropriate level of event description with which to work, conceivably HFACS could be used to connect latent failure points from the organizational level through supervision and workplace setting to link to the human error.

In contrast, HERA is a detailed analytic technique that provides output data at the individual level on specific cognitive processes and has been useful in prospective diagnoses of potential failure points in prototype systems. The output from a HERA analysis is a more discrete item listing of the various dimensions of the analysis and identifies specific cognitive processes and psychological error mechanisms.

The results of this evaluation suggest that there is little specific overlap in the type of outputs from each technique. However, the results of the two methods can be connected through their conceptual underpinnings. For example, Decision Errors in HFACS are captured in HERA by the Cognitive Domain of Judgment, Planning, & Decision Making (e.g., an incorrect decision or plan resulting from a failure to consider side effects).

This was a preliminary study to determine whether the two approaches could be harmonized into one approach. The results were limited by the narratives used for analysis because the current requirement for reporting separation events does not adequately capture specific information about the working environment, supervisory acts, and organizational influences. Thus, each technique alone could not demonstrate its ability to fully capture data at these levels. Harmonization of the two techniques has the potential to expand the breadth and depth of the analysis to capture the human factors that contributed to the incident/accident.

Efforts are currently underway to harmonize the two techniques. Future work will replicate this study using multiple SME analysts, US and European incident reports, complete the proposed harmonization and validate the technique's utility with both retrospective analysis of incident cases and prospective analyses as part of the design of future systems.

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